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# **THE INNOVATION ELEMENT OF THE DIPLOMA (B.ENG.) PROGRAMS AT DTU**

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## **ABSTRACT**

In September 2014 the first version of the newly developed CDIO-based diploma (B.Eng) programs were launched at DTU (Nyborg et al., 2015). The programs are the result of a comprehensive merger process of former diploma programs, namely the programs at Engineering College of Copenhagen (now DTU Diploma) and the Technical University of Denmark.

The most significant new activity in the programs is the introduction of a common 10 ECTS compulsory course in innovation in the later part of the programs.

The idea behind this course is to give students the opportunity to collaborate on inter-disciplinary real-life projects. This course strengthens not only innovation skills but personal and interpersonal skills as well.

In this paper we will discuss the organization of the Innovation Pilot course. In particular we focus on:

- Structure of programmes
- Organization of the Innovation Pilot course
- The didactical considerations
- Scaling up the course from 50 to 500 students

## **KEYWORDS**

CDIO-based study programs, Stakeholder involvement, Innovation, Standards: 1, 2, 3, 6, 7, 8 9,11

## **INTRODUCTION**

In general, innovation can be seen as the process of translating an idea into a good or service that creates value for which will. Hence, innovation includes an economical aspect and can be considered as the results that occur when new ideas are matured and marketed by a company in order to satisfy the needs and expectations of the customers. In a learning context innovation can be understood as a process where an organization creates and defines problems and then actively develops the necessary knowledge to solve them (Nonaka 1994, p. 14).

In 2011 the CDIO syllabus was updated to version 2.0 (Crawley et al., 2011). Particularly attention was given to innovation, invention, internationalization and sustainability. Modifications in content and in labeling have been incorporated into the new version of the syllabus. In essence innovation is considered as a market-oriented view of what the CDIO Syllabus defines in Sections 4.2 through 4.6.

At DTU, innovation is considered multidisciplinary and involves companies in the process. In order to support innovation as an educational element, this calls for three important things in the curriculum design:

- Establishing a platform for collaboration between different study lines
- Creating a learning space where students can acquire innovation skills
- Scaling up the course

At DTU it was decided to create a compulsory 10 ECTS course “Innovation Pilot” (Technical University of Denmark, Course description 62999), focusing entirely on interdisciplinary-innovation and including the parts mentioned above.

The idea behind the course is, as the name suggests, that students should be trained to act as pilots for innovation projects in collaboration with companies.

## STRUCTURE OF PROGRAMMES

All B.Eng. programs at DTU follow a common structure (Figure 1). On the first four semesters, all courses are compulsory. With some variation, this is followed by a semester with elective courses, a semester with industry internship and a semester with the final B.Eng. thesis. Each semester consists of a lecture period (13 weeks) and a lab-period (three weeks). On the first four semesters, the projects are design-build projects. The projects are attached to a 10-ECTS-point course with contributions from one or more supporting courses. Typically these projects range from simple design-build projects focusing entirely on the “DI” part of CDIO (Nyborg et al., 2010), to stand alone projects where all elements i CDIO come into play (Sparsø et al., 2011). The projects not only provide the students technical knowledge but also train the students’ personal- and interpersonal skills.

Period	13 week	3 week
ECTS	25	5
1. Semester	Compulsory courses + CDIO project	
2. Semester	Compulsory courses + CDIO project	
3. Semester	Compulsory courses + CDIO project	
4. Semester	Compulsory courses + CDIO project	
5. Semester	Elective courses ( 20 ECTS + <b>Innovation Pilot course (10 ECTS)</b> )	
6. Semester	Industry internship	
7. Semester	Elective courses (10 ECTS) + final thesis (20 ECTS)	

Figure 1: Semester structure (example)

The Innovation Pilot course is placed after the compulsory part of the curriculum. Beyond the technical content, the students have at that point gained experience in CDIO syllabus categories 2, 3 and 4 through semester CDIO projects. The ability to collaborate on each study line is well developed.

## ORGANIZATION OF THE INNOVATION PILOT COURSE

The overall course schedule is shown in Figure 2: Course structure and schedule.

### INNOVATION PILOT LECTURE PLAN SPRING TERM

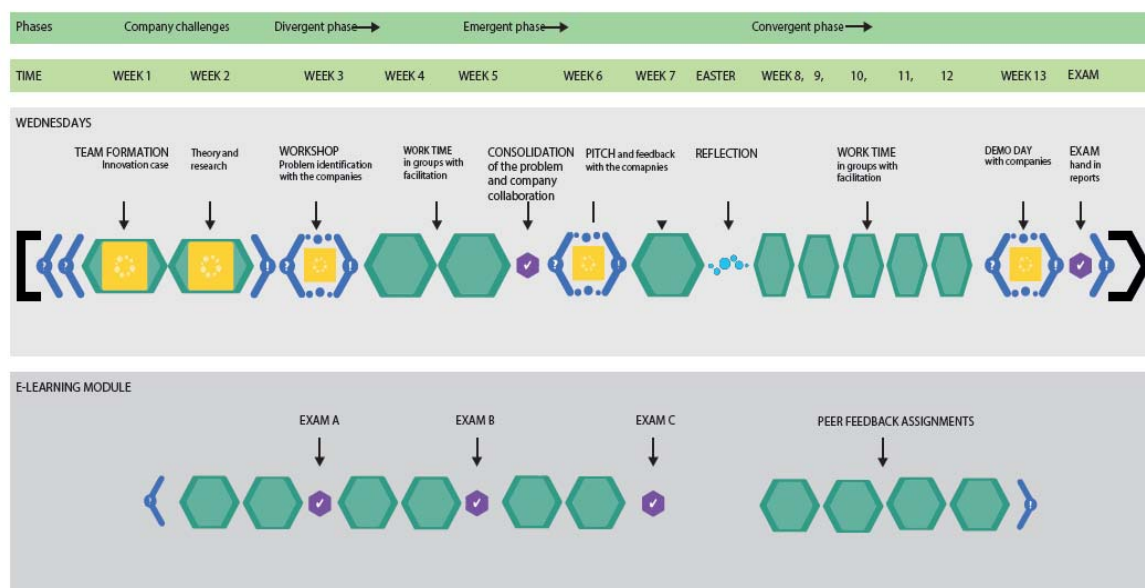


Figure 2: Course structure and schedule

The Innovation Pilot course is offered three times a year in the two lecture periods and as an intensive summer school (6 weeks). There are 17 study programs (disciplines) involved, and it is expected that up to 500 students will take the course at the same time. They are divided into smaller units, thematic labs of up to 40 students, running in parallel. The teams are formed so that they consist of 4-6 people with a minimum of two disciplines present and 2 teams are expected to work with the same companies or similar external partners. The students are responsible for finding ways to apply their unique skills and knowledge to create value in the projects. The structure and example of lab themes are shown in Figure 3: Structure of labs.

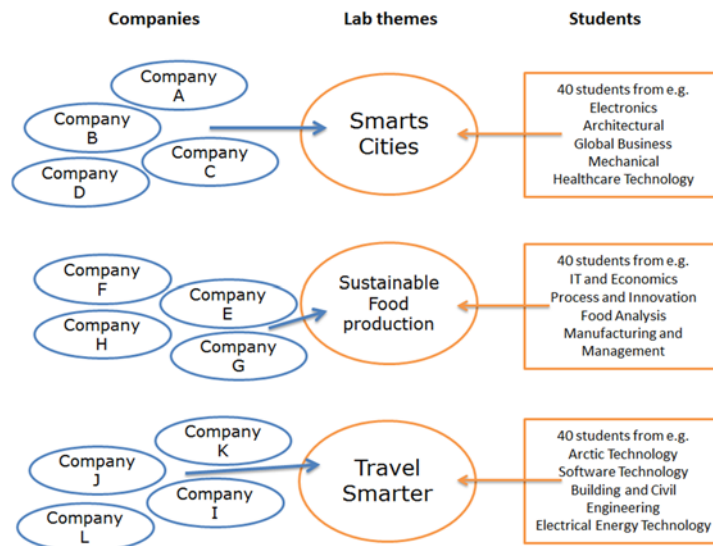


Figure 3: Structure of labs

The course will be facilitated by *lab leaders*, teacher teams of engineering experts and innovation experts that will act as supervisors ensuring a high academic level in both areas and stimulating the inter-disciplinary learning environment.

The course is run as a blended learning course with use of e-learning, and peer feedback alongside the weekly classes. (Norman et al, 2014) This to optimize the time the students have, to work together in teams (one full day a week) and free up supervisor time to facilitate and work with the teams.

The projects take a starting point in actual needs experienced in the partner companies, they are then reformulated as open-ended projects and explored holistically by getting out of the building involving users, customers, stakeholders etc. see Figure 4.

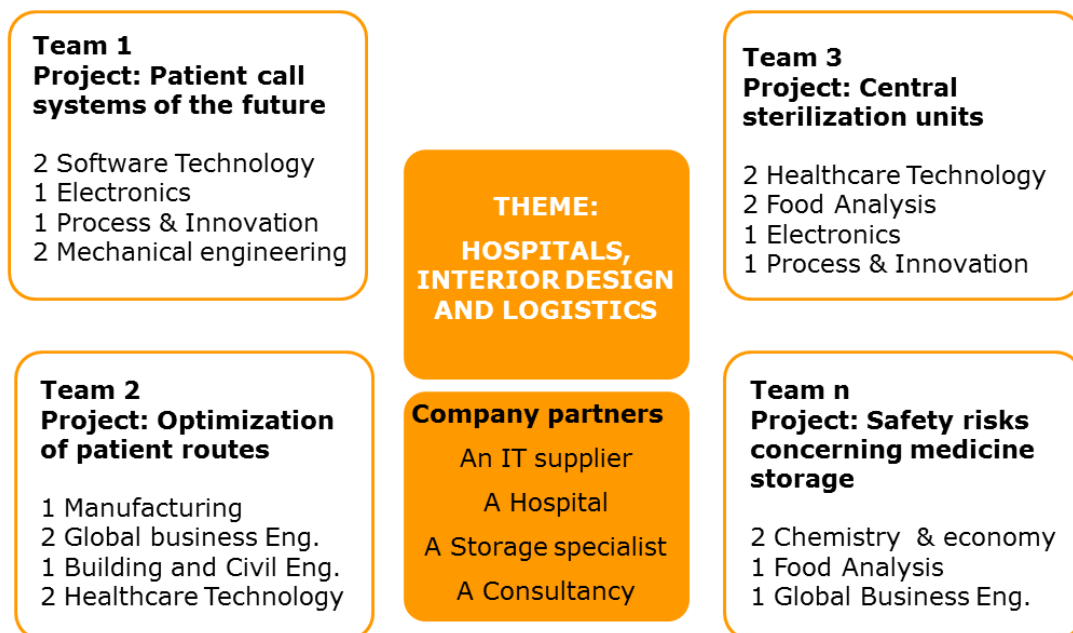


Figure 4: Example of projects in a lab

The team then narrows in on a problem and after adjusting expectations with the company, work towards a corresponding solution. All the way through the course they work on creating prototypes or mock-ups in the labs.

On the final day of the course, a Demo Day is held where all projects gather and the students pitch their findings and demonstrate their prototypes to their company partners and get feedback on these. The feedback is included in the reflection report.

The process and work with acquisition of teamwork and innovation competencies is evaluated in a reflection report building on weekly reflections from individuals and teams. The reflection concerns: The teamwork and how the team has managed to bring their diverse knowledge and contributions into play, the use of innovation methods and how they have managed the company collaboration.

The course is evaluated as a written exam. In order to attend the exam the students must have a participation rate above 80% and have uploaded the weekly assignments and logs. The evaluation is an overall assessment of the following elements: a) An innovation proposal and a prototype, b) a reflection report and c) 3 smaller multiple choice exams from the e-learning module. Part a and b each weigh 40 % and c 20%.

The intention is to balance the assessment of the process oriented development of personal skills and the product oriented results of the innovation project in the format of an innovation proposal and prototype and finally the knowledge aspect which is measured in the multiple choice exams.

The course is supported by a course responsible working with a small administrative unit that support the acquisition and screening of company projects, the formulation of lab themes, the selection and training of supervisors (teachers) and the events held in connection with the course.

The themes serve as platforms of common interest for students, supervisors and companies. They have to be broad enough to be relevant for all 17 study lines, concrete and interesting enough for the students to choose the theme and not least relevant for the company challenges.

## **ESTABLISHING A PLATFORM FOR COLLABORATION**

The main challenge in establishing a platform has been to have the students actually meet in interdisciplinary teams. Each study line has had the freedom to place the course freely on the 5<sup>th</sup> or 6<sup>th</sup> semester depending on their study plans. This has created a need to offer the course both in the spring and fall semester. Furthermore, the students are also encouraged to take their electives semester abroad creating a need for the course to be offered as an intensive course outside of regular study periods. All in all it is very hard to predict numbers as well as what study lines will be present at what time.

This is further complicated by the different sizes of study lines that range from 30 students to 200 students per semester and the fact that some study lines are offered twice a year while others only once.

The Innovation Pilot course is therefore offered three times a year in the two lecture periods and as an intensive summer school (6 weeks). This creates flexibility for the study lines and not least for the students but on the other hand have costs on how detailed it is possible to plan for each specific study line and the freedom of choice each individual student has.

## **DIDACTICAL CONSIDERATIONS REGARDING CREATING A LEARNING SPACE WHERE STUDENTS CAN ACQUIRE INNOVATION SKILLS**

The course design has been influenced by innovation literature in a number of focus areas concerning:

- Innovation seen as knowledge creation
- The role of diversity
- The teacher role when teaching new competencies
- The role of motivation and the company context

They will be elaborated upon in the following section.

### ***Innovation as a knowledge creation process***

In order to teach students the skills needed to create and implement value creating innovations, an understanding of what innovation entails is needed. According to Nonaka (2007) innovation equals knowledge creation which means that we surpass the expectations of the CDIO syllabus that only strive for knowledge discovery (Crawley et. al. 2011).

*“The essence of innovation is to re-create the world according to a particular vision or ideal. To create new knowledge means quite literally to re-create the company and everyone in it in a nonstop process of personal and organizational self-renewal.” (Nonaka, 2007, p.164)*

This is aligned with the perspective of the student as knowledge creator rather than capturer of knowledge (Normann et al., 2014, p. 3) and underlines the need to create a lab where students can experiment with this knowledge creation.

In Innovation Pilot this is addressed in that the students will work with the company unfolding the original problem the company has provided and spend the first half of the course learning to create knowledge by openly exploring the problem and the assumptions behind it before trying to solve it.

### ***Innovation is created with others – the role of diversity***

An important aspect is that innovation learning is richer when performed by a diverse group bringing in both more knowledge as well as more ignorance. However, as diversity so often is only present but not actively used (Justesen, 2007), the knowledge creation however calls for social skills as well as motivation for using it.

Darsø (2012) introduces, based on her empirical studies of innovation, two dynamics that should be navigated when creating innovation learning. The knowledge dynamic between knowledge and ignorance and the communication dynamic between concepts and relations. The knowledge-ignorance dynamic is important as she found that just as important subject knowledge was, just as stifling to the innovation process could it be when expert statements were taken for granted and not examined. In this way, the misunderstandings arising when different disciplines work together become an important source for innovation.

As for the concept and relations dynamic, she argues that the relations are what enhances the ability of the team to use the knowledge and ignorance effectively. She sums up innovation competencies as:

*“The ability to create innovation by navigating together with others under complex situations.”*

It consists of two types:

- Socio-innovative competencies: Mastering social interaction that enhances innovation.
- Intra-innovative competencies: Consciousness & sensitivity in relation to own and others' talents, preferences & potential for development and innovation. (Darsø, 2012)

In Innovation Pilot these are addressed by placing the students in interdisciplinary teams of 4-6 people with a maximum of two representatives from the same discipline and then include a huge focus on their team collaboration in both the course and the examination. This because although all have extensive experience with project- and team work, they are not necessarily very practiced in working actively with the communication dynamic between concepts and relations and the consciousness regarding own and others' talents.

However as this course is also a first for most of the students, flipped classroom techniques have been applied (Normann et. al 2014) and an Innovation Basics e-learning module has been developed. The idea is that the students spend time on their own acquiring this knowledge and time together practicing the application.

In order to create constructive alignment they are during the exam measured on their ability to *"Use their own as well as other's skills, preferences and potential in an interdisciplinary project. In addition, be able to argue for major decisions, put in relation to both own and other's skills."*(ibid)

### ***Teaching personal competencies creates a new teacher role***

Advances in innovation pedagogics demands that the teacher role changes to facilitator, focusing just as much on the process of the teams as the outcome of the project work (Darsø, 2012). This is experienced as a huge shift for the supervisor compared to regular engineering project supervision (Christiansen et al., 2014)

In Innovation Pilot, a mandatory preparatory course is given to all teachers participating in the course and they are offered supervision and help from a support staff regarding this role.

### ***Innovation learning requires motivation***

That learning is enhanced by motivated students is probably a universal truth. However, acquiring innovative skills entails unlearning previous ways of thinking in order to create new knowledge, in other words: Transformative learning (Illeris, 2004). Furthermore, handling ambiguity in an open-ended project with team members emphasizes this need. Amabile who has done extensive research points to that motivation, expertise and creative thinking skills (Amabile, 1998) are needed to create creativity – the predecessor of innovation.

In the Innovation Pilot course the intrinsic motivation is challenged by it being a mandatory course. This is a challenge for more reasons. First of all, there is an added pressure to pass the exam tipping the balance towards extrinsic motivation. Secondly, not all students, nor their teachers see the need or relevance to study innovation as part of their engineering studies. Thirdly, it seems to have a motivation-lowering effect when students are matched up in teams where motivation levels are unbalanced.



Amabile (1998) recommends four initiatives to boost intrinsic motivation:

1. Match the right people with the right assignment
2. Let people know that their work matters
3. Give people freedom within the company's goals
4. Allocate appropriate amounts of time and project resources

The first one is impractical as the projects are open-ended and logistics involved in creating interdisciplinary teams make it hard to predict which types of students that will be in each lab and team. Instead, the course works with the principle of shaping the project to be right for the team. This involves encouraging the students to be not only objective but instead together with the knowledge they create, let their personal preferences and disciplinary strengths, guide the problem definition and determine the focus of their final solution.

The company collaboration plays a huge role in motivating the students. Furthermore, successful engineers from the industry are invited to talk about the importance of innovation skills. Also on a university level there has been an effort to stimulate ambassadors among students and teachers to stimulate a sense of relevance.

The before mentioned logistics also do not allow the students to neither choose favorite co-workers nor the specific company to work with. To allow them a freedom within the frame, each lab-unit of 40 students is matched with an overall broad theme such as FinTech or Smart Cities and the students themselves prioritize what themes they are most interested in. This also creates a first common ground for the teams that again are formed by the students themselves. The direction of the project is likewise a student decision although it has to be negotiated with the company.

The fourth factor is addressed in the process of scoping company problems that can be addressed within the semester period and the students' innovation competencies as well as the course plan. This will have to be balanced through experimentation in the first implementations.

### ***The company context as arena for learning***

The first principle of CDIO is that "the conceiving-designing implementing-operating of products, processes and systems should be the authentic context of engineering education." (Crawley et al., 2011). This is a good match for the *Complex situation* that is core of the innovation competency (Darsø, 2012).

The complex situation in the Innovation Pilot course is that the problem is owned by a company and that the knowledge generating process should involve their reality. In this way the implement-operate part of CDIO is addressed by the business approach to the solutions. The students cannot make generic technological solutions, not taking into account the context they are made in. Instead they have to spend time analyzing the company they work with, and address in an innovation proposal as well as pitch why this particular solution makes sense for their partner company from a business, society, organizational, operational and technological perspective.

This will obviously entail a risk that the students are affected by the company's perception of what is possible and not possible, and therefore is another focal point in the training of their supervisors.

## SCALING UP THE COURSE

In the spring of 2016 a pilot course is held as an elective for approx. 50 students. In the autumn when it starts to be mandatory, 230 students are expected to enroll and that number grows to 500 in the spring of 2017. This also means that the teacher group grows from 4 in the first run to 12 in the autumn and to 24 in the spring of 2017.

There is a paradox between a very individualized facilitation of the development of personal competencies between students, with very different prerequisites, and the need to deliver a standardized learning outcome of the course.

The teacher job is very complex, as the facilitator of the team should facilitate individually among 40 students. The overall design of the course involves a standardized frame for running the course and an e-learning support module. Beyond that, there is a huge degree of decentralized freedom for the supervisors to facilitate the teamwork. Another choice has been made to only do a written exam, which has demanded for a varied hand-in of material in order to evaluate the learning and collaboration. This has been further complicated by Danish law stating that all written material must be traced back individually going directly against the pedagogical intent of having the team collaborating closely. This has been attempted mitigated by asking for a shared schematic overview of all contributions including writing but also other teamwork contributions related to the innovation process.

## CONCLUSION AND FINAL REMARKS

Interdisciplinary innovation arises from the positive effects that result when stepping across the technical and social boundaries by which we normally structure knowledge.

In the knowledge economy, it is often the case that the right knowledge to solve a problem is in a different place than the problem itself. Also, many problems today need more than one kind of knowledge to solve them, so interdisciplinary innovation is an essential tool for the challenging problems of today.

All engineering disciplines have their own way of addressing a problem. On one hand this means a highly specialized knowledge, but on the other hand it also narrows the way of thinking and hence not always asking the right questions.

The Innovation Pilot course defines a framework for collaboration between different engineering disciplines. It is anticipated that the synergistic effect that occurs, breaking those discipline boundaries, will lead to smarter solutions to problems that companies might have.

By designing the course in this way it has been possible to scale a single course to quite a few students while maintaining a focus on teaching innovation competencies.

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### ***Biographical Information***

Mads Nyborg is an associate professor in software engineering at DTU Compute. He has several years of experience in teaching software engineering and has governed industrial projects both as a consultant on innovative projects and as a supervisor for student projects. He was the one of the primary movers in introducing the CDIO concept at the diploma programme at DTU Compute.

Nynne Budtz Christiansen is an associate professor in Intrapreneurship and innovation at DTU Diploma. She has years of experience in teaching cross-disciplinary teams of engineering students intrapreneurship and innovation skills in collaboration with industry. She has led several projects furthering industry collaboration at the diploma programmes at DTU Diplom.

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